LIFE CYCLE COST ANALYSIS OF SHUTTLE-DERIVED LAUNCH VEHICLES

EXECUTIVE SUMMARY

VOLUME II

DRD MA-857T

PREPARED BY

ECON INCORPORATED

FOR

NASA/JOHNSON SPACE CENTER

ON CONTRACT NAS9-16410

SEPTEMBER 1982

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ABSTRACT

This study, "Life Cycle Cost Analysis of Shuttle-Derived Launch Vehicles", was performed under Contract NAS9-16410 for the Lyndon B. Johnson Space Center (JSC) of the National Aeronautics and Space Administration (NASA).

ECON, Inc. conducted an independent assessment of SDLV development, production and operations costs. This assessment was performed using only the design, performance and programmatic definition of the Shuttle-Derived Launch Vehicle (SDLV) concepts as established by Martin Marietta and Rockwell International, the two contractors performing SDLV conceptual studies under separate contract to NASA.

ECON also evaluated the relative life cycle costs of space transportation systems using the Shuttle alone in comparison to a mix of Shuttle and SDLV vehicles. These results were tested against a range of mission activity levels.

The final objective of this study was the calculation and comparison of the costs for alternative SDLV concepts. All costs were estimated in constant 1982 dollars.

The Final Report summarizes the results of all study efforts associated with ECON's independent assessment of life cycle costs for SDLV concepts. It is structured in two volumes; Volume I, the Technical Report and Volume II, the Executive Summary.

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BACKGROUND

SCOPE OF STUDY

- TWELVE MONTHS
- $50,000.00

OBJECTIVES

- COMPARE LCC OF SDLV/SHUTTLE MIX WITH SHUTTLE ONLY
- EVALUATE LCC DIFFERENCE BETWEEN SDLV CONCEPTS
- TEST SENSITIVITY TO MISSION SCENARIO

DIFFERENCES FROM MIDTERM REPORT

- IMPROVED SYSTEM DEFINITION
- SOFTWARE COSTS PER PRICE 'S'
- POP 81-2 AND INDEPENDENTLY-EVALUATED STS COSTS
- P/A MODULE FLEET SIZED FOR UNCERTAINTIES
- MISSION MODEL TREATED PARAMETRICALLY

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GROUNDRULES

1982 CONSTANT DOLLARS

TYPICAL FEE LEVELS

SHUTTLE ACQUISITION COSTS CONSIDERED SUNK

- ALL DEVELOPMENT COSTS
- PRODUCTION OF FOUR ORBITERS PLUS INITIAL SPARES

SDLV ACQUISITION COSTS AMORTIZED

- ALL DEVELOPMENT COSTS
- PROPULSION/AVIONICS MODULE FLEET ACQUISITION

SDLV DEVELOPMENT PROGRAM

- ONE COMPLETE FLIGHT VEHICLE
- ONE TEST FLIGHT

COMMON STS/SDLV HARDWARE & OPERATIONS COSTS SHARED

- CUMULATIVE AVERAGE COSTS, 1983-2000
- AVERAGED OVER TOTAL FLIGHT QUANTITY

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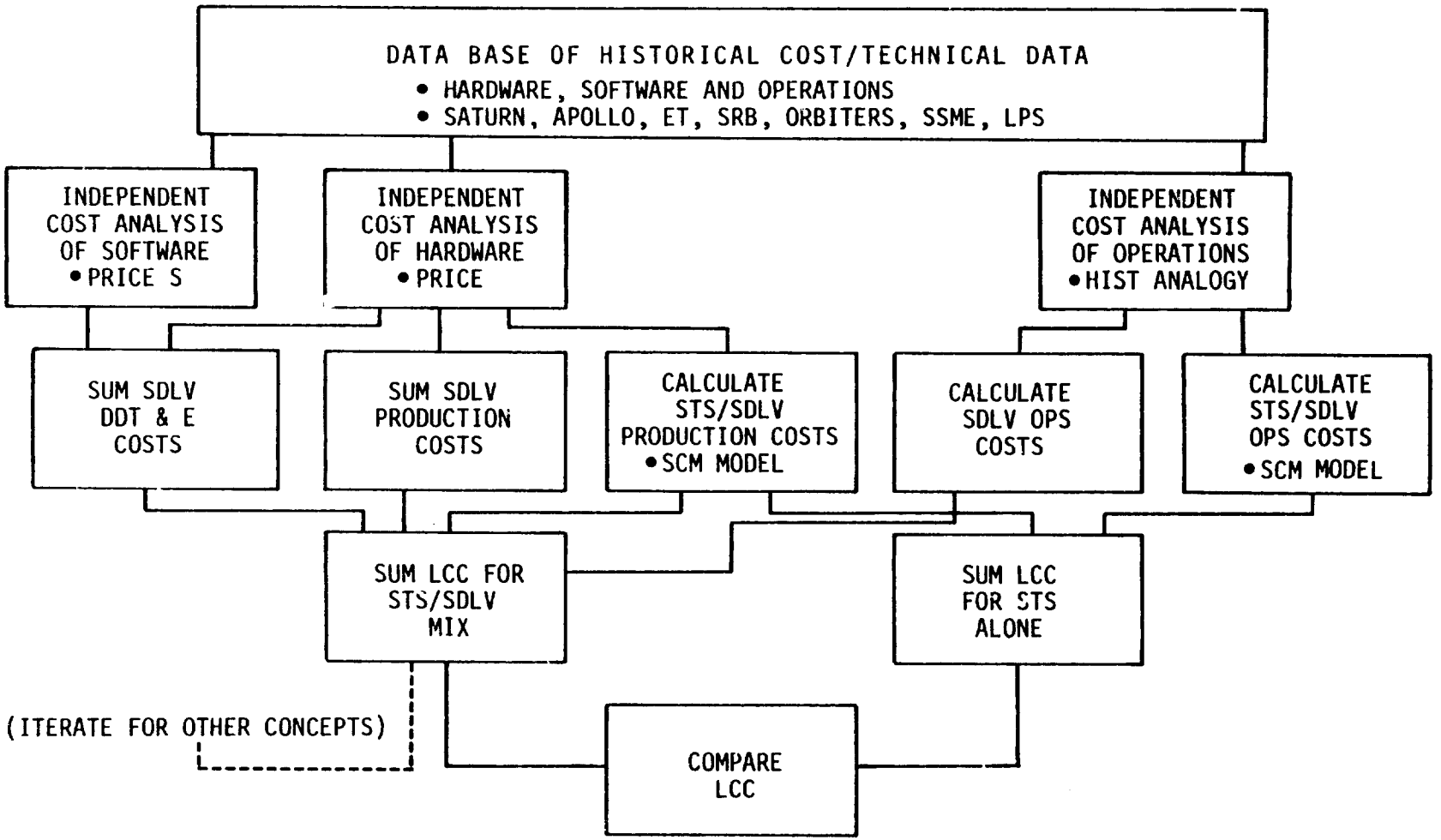
SIMPLIFIED STUDY LOGIC



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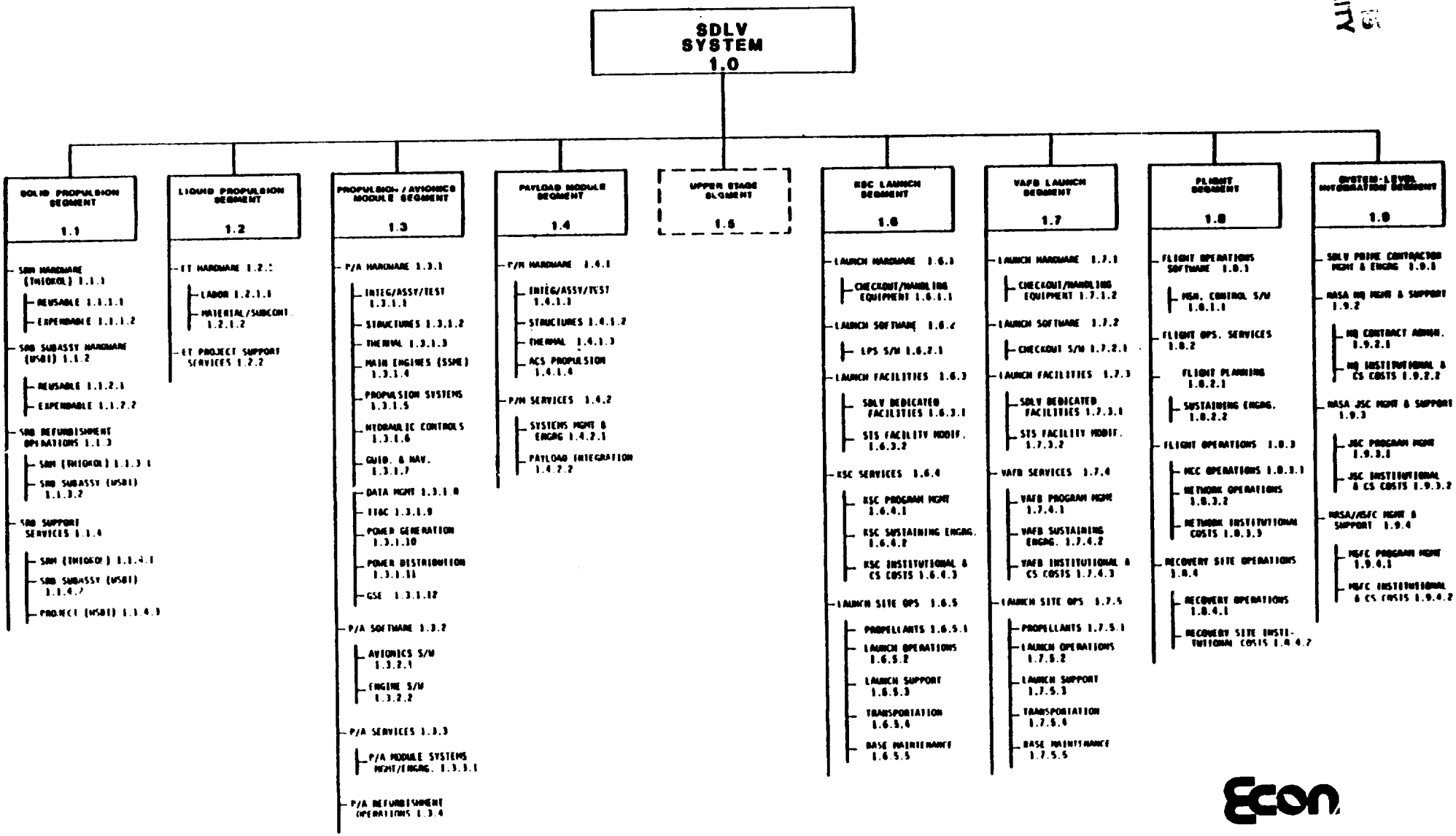
WORK BREAKDOWN STRUCTURE



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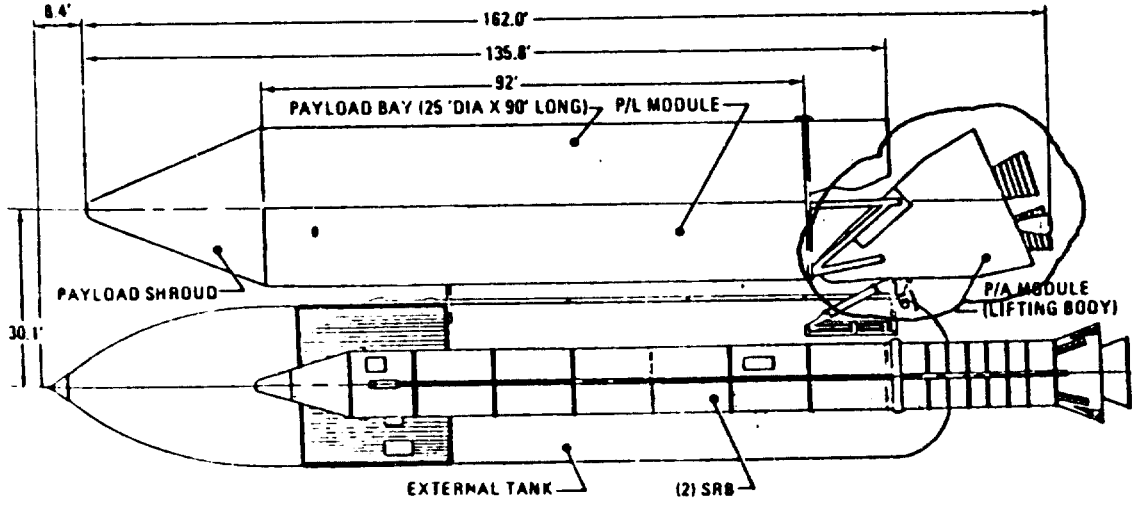
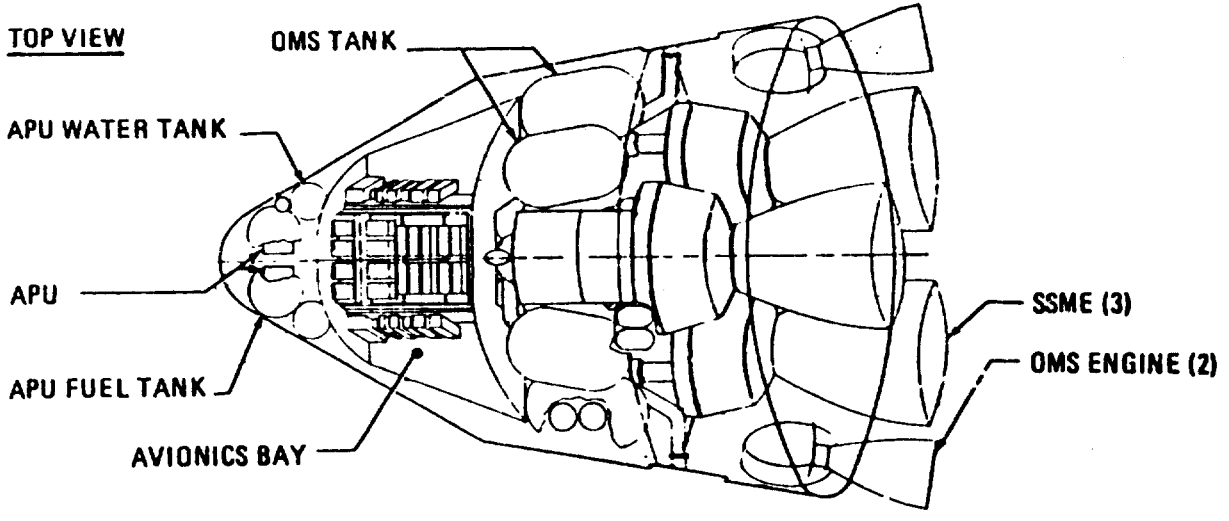
REFERENCE CONFIGURATION



MAJOR ELEMENT WEIGHTS		
	INERT	LOW
CARGO CARRIER		289,397
• PAYLOAD	147,587	
• P/L MODULE	47,555	
• P/A MODULE	45,992	
• SSME	20,976	
ET	70,990	1,642,295
SRB	300,420	2,514,420
GLOW		4,446,112



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P/A MODULE WEIGHT SUMMARY

ITEM	WEIGHT (LB)
STRUCTURE	16,586)
THRUST STRUCTURE	3,496
BODY (SHELL)	3,519
WING	---
TPS	5,295
INTERNAL STRUCTURE	4,276
LANDING AND RECOVERY	(6,706)
PARACHUTES	3,485
LANDING GEAR/LEGS (4)	3,221
PROPULSION	(4,845)
RETRO ROCKET MOTOR	1,320
HELIUM TANKS (MPS)	1,275
OMS SUBSYSTEM	
ENGINES (2)	598
HELIUM TANKS (2)	558
PROPELLANT TANKS (4)	1,040
MISC.	54
SSME (3)	(20,976)
ACTIVE THERMAL CONTROL SYSTEM	(1,126)

ITEM	WEIGHT (LB)
RCS SUBSYSTEM	(9,957)
PRIMARY THRUSTERS	551
VERNIER THRUSTERS	38
MISC.	241
MAIN FEED SUBSYSTEM	4,193
AUXILIARY SUBSYSTEM	4,934
POWER	(3,272)
APU (HYDRAULIC)	1,225
FUEL CELLS (2)	400
FUEL CELLS TANKS (2)	294
CABLING	428
BLACK BOXES	443
MISC.	482
AVIONICS	(3,500)
BLACK BOXES	1,425
ANTENNAS (4)	4
CABLING	2,071
P/A MODULE DRY WEIGHT	66,968

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PROPULSION/AVIONICS MODULE HARDWARE COSTS

WBS #	WBS IDENTIFICATION	ESTIMATED COSTS ($M 1982) DDT & E COST	PRODUCTION COST (3 UNITS)	TOTAL ACQUISITION COST
1.3.1.1	INTEG/ASSY/TEST	129.5	49.0	178.6
1.3.1.2	STRUCTURES	251.6	164.6	416.1
1.3.1.3	THERMAL	210.4	113.9	324.3
1.3.1.4	SSME	236.0	429.0	665.0
1.3.1.5	PROPULSION SYSTEMS	149.2	171.4	320.6
1.3.1.6	AUXILIARY SYSTEMS	76.1	19.3	95.4
1.3.1.7	GUIDANCE & NAVIGATION	27.2	36.3	63.5
1.3.1.8	DATA MANAGEMENT	34.5	45.2	79.7
1.3.1.9	TT & C	10.5	14.2	24.7
1.3.1.10	POWER GENERATION	17.6	18.9	36.5
1.3.1.11	POWER DISTRIBUTION	63.3	30.0	93.3
		1205.9	1091.8	2297.70

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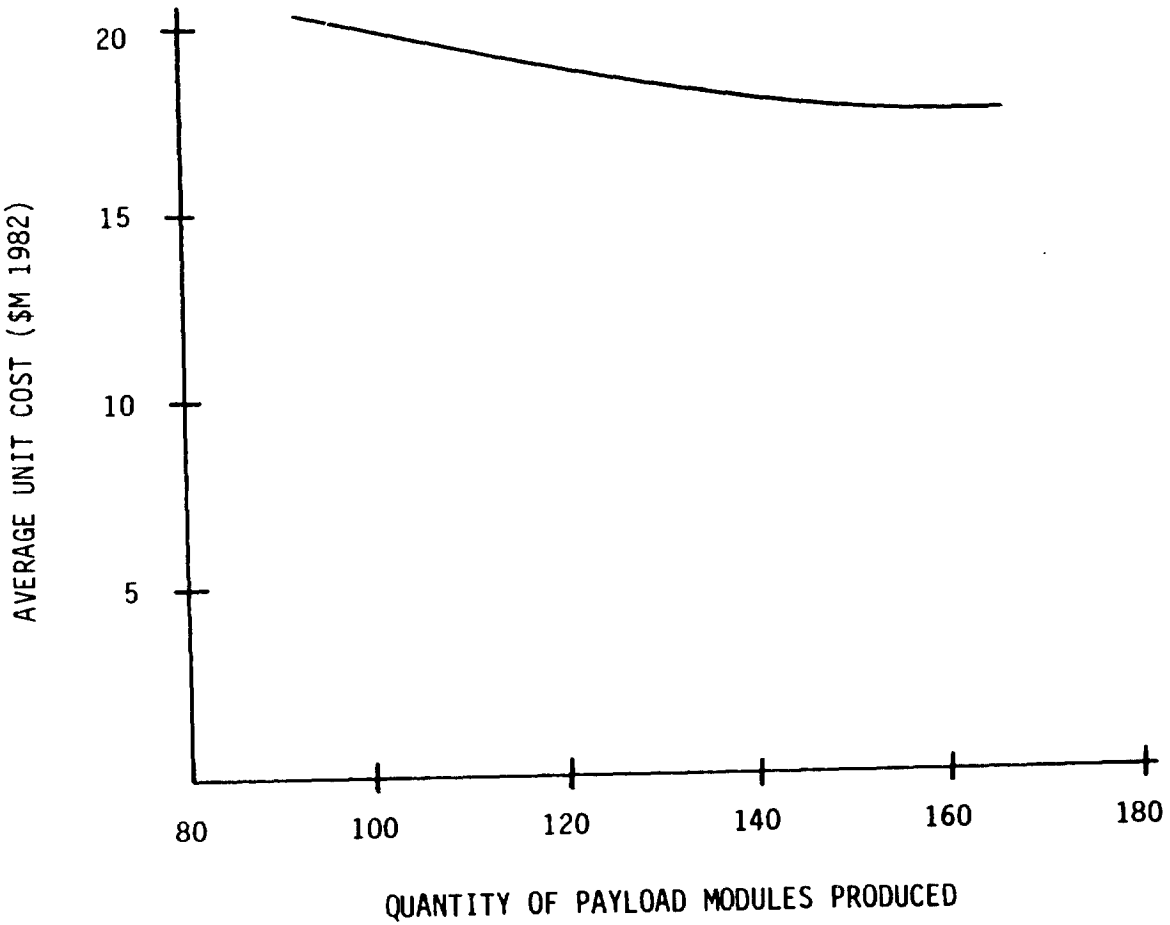
PAYLOAD MODULE COST/QUANTITY RELATIONSHIP



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SOFTWARE ACQUISITION COSTS

WBS #	WBS IDENTIFICATION	EST. # OF MACHINE INST.	— FRACTION NEW — DESIGN	CODE	DDT & E COST ($M 1982)
1.3.2.1	P/A MODULE AVIONICS S/W	60,400	0.9	1.0	45.789
1.3.2.2	P/A ENGINE CONTROL S/W	12,500	0.1	0.1	2.369
1.6.2.1	KSC LAUNCH PROCESSING SYSTEM S/W	1,710,000	0.25	0.5	19.911
1.7.2.1	VAFB LAUNCH S/W	1,710,000	0.05	0.1	5.552
1.8.1.1	MISSION CONTROL S/W	2,695,000	0.1	0.2	25.399
1.8.2.1	FLIGHT PLANNING	910,000	0.5	1.0	14.088
					113.108

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P/A MODULE SOFTWARE TRADE RESULTS

	(SOFTWARE DDT & E COST)	
	MODIFIED ORBITER SOFTWARE	NEW SOFTWARE, NEW MACHINE
ORBITER S/W CONTRACTOR	$ 24.80M	
NEW CONTRACTOR	$ 43.65M	$ 45.79M

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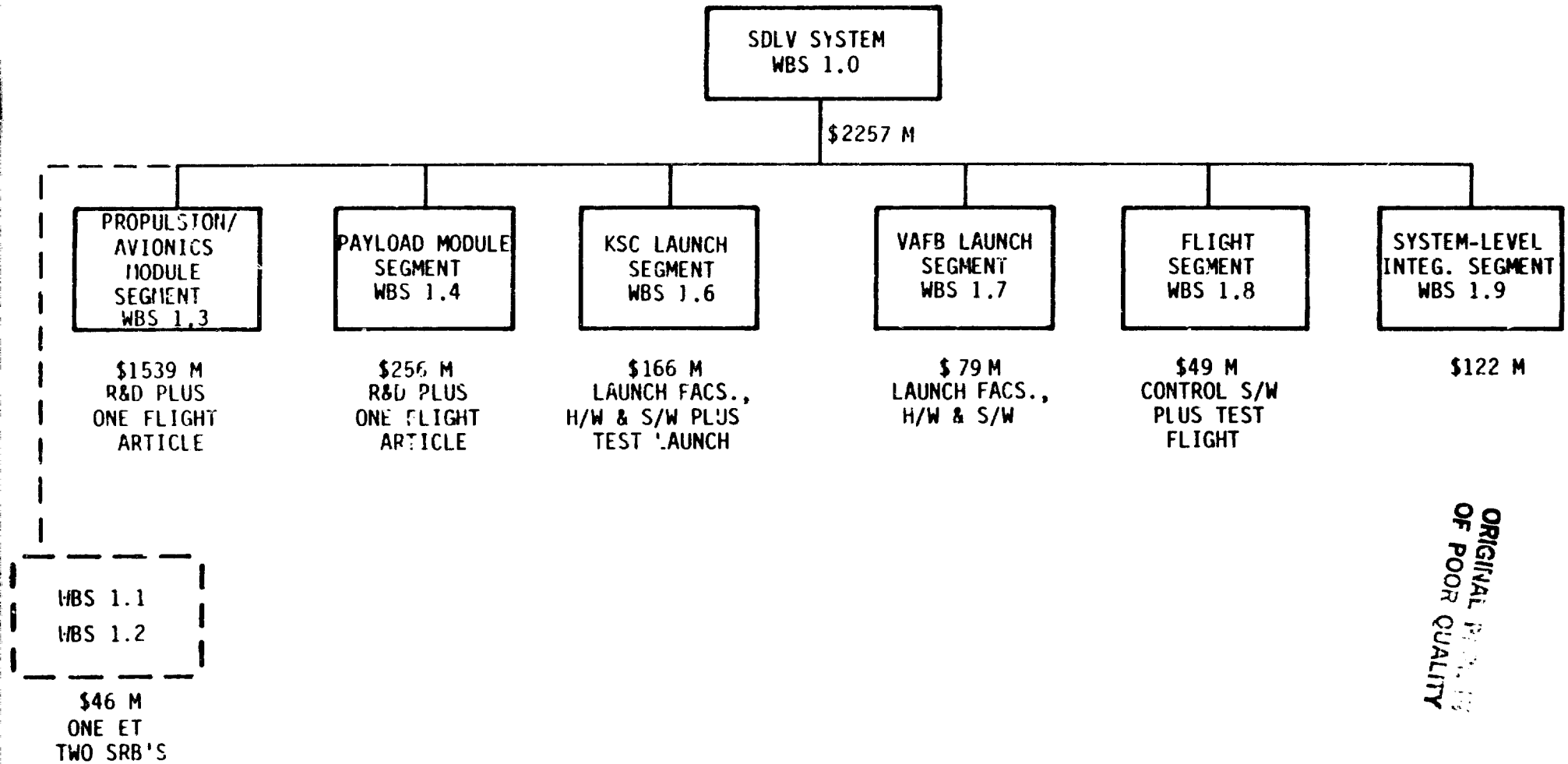
DDT&E ESTIMATE



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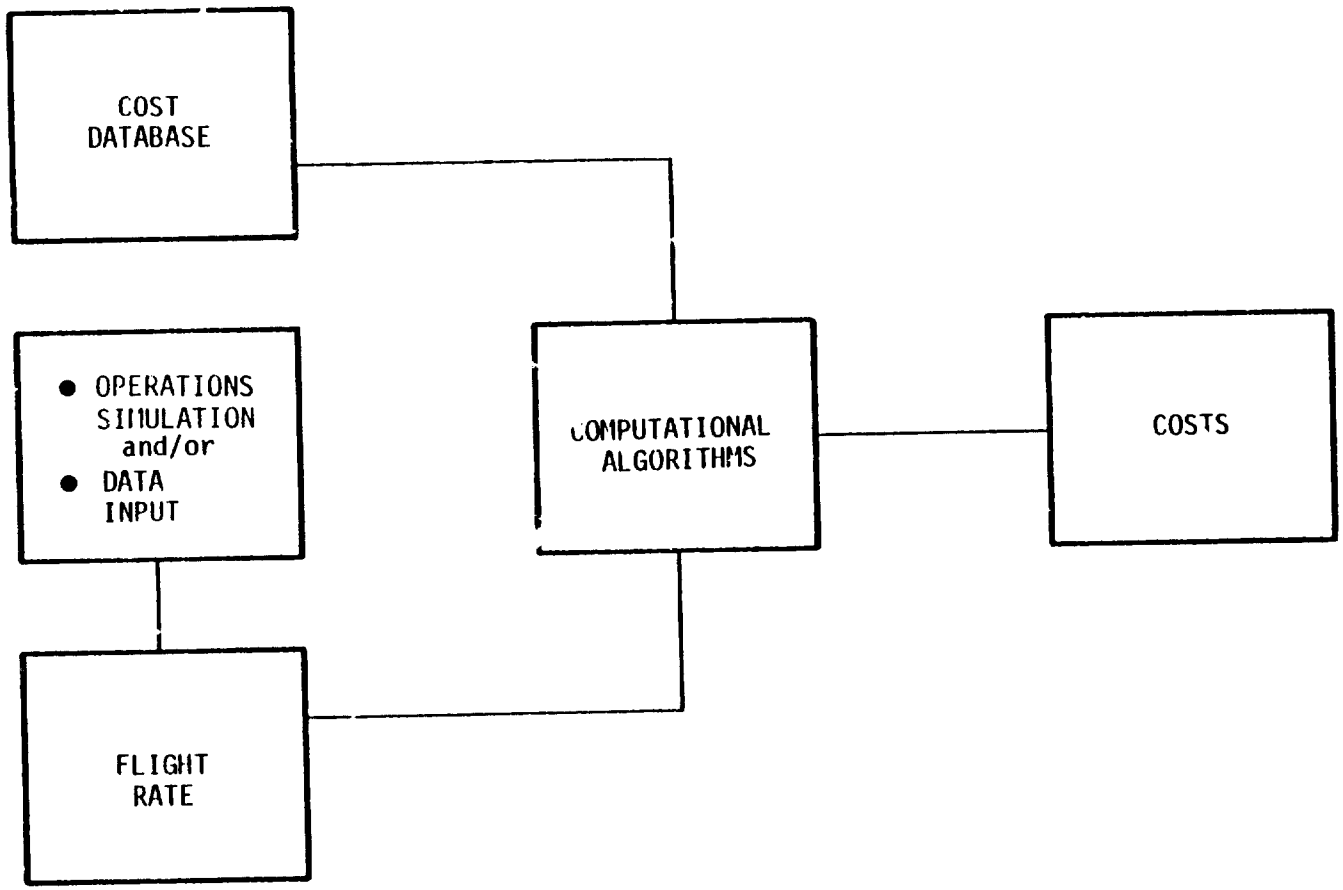
SCP COST MODEL OVERVIEW



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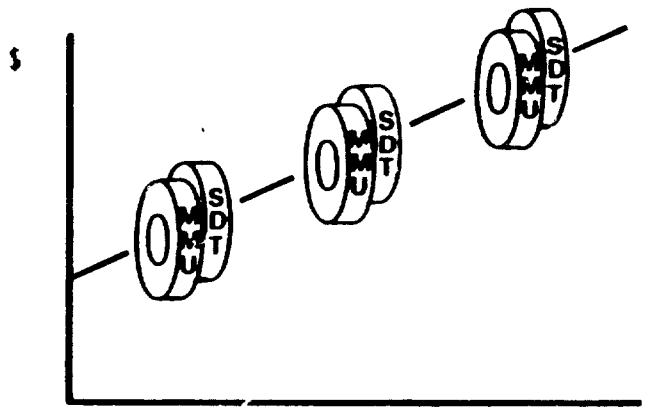
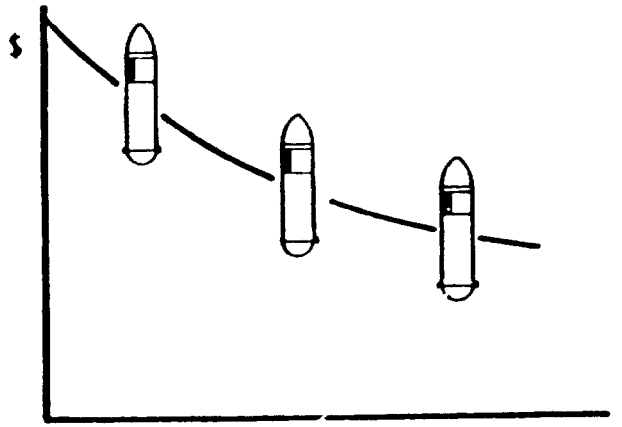
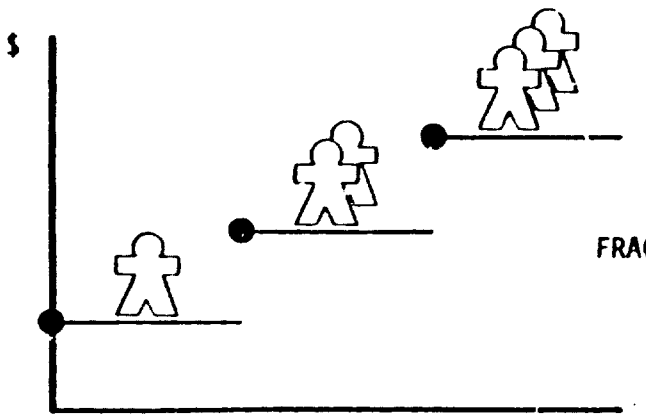
TYPES OF SCP COMPUTATIONAL ALGORITHMS



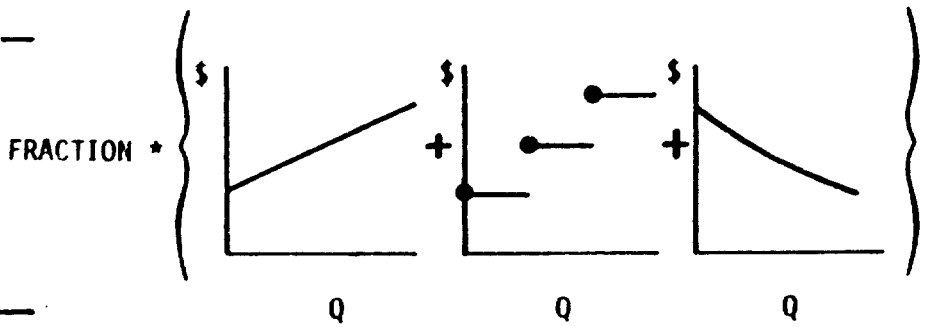
ALGORITHM 1



ALGORITHM 3



ALGORITHM 2



ALGORITHM 4

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DISPOSITION OF SCP-GENERATED COSTS IN SDLV ESTIMATES

COST NUMBER	COST CATEGORY	APPLICABILITY TO SDLV: USED DIRECTLY	APPLICABILITY TO SDLV: USED FOR REFERENCE	APPLICABILITY TO SDLV: NOT APPLICABLE	COSTS SHARED BETWEEN STS AND SDLV TRANSPORTATION SYSTEMS	SDLV WBS NO.
E1	ORBITER SPARES		X			1.3.4
E2	ORBITER RECURRING SUPPORT		X			1.3.3.1
E3	FIELD SUPPORT, JSC			X		
E4	REPLACEMENT GFE			X		
E5	FLIGHT DESIGN, PHASE 1		X			1.8.2.1
E6	FLIGHT DESIGN, PHASE 2	X			AVERAGE COST/FLIGHT	1.8.2.1
E7	MCC OPERATIONS	X			PRORATA ANNUAL COST	1.8.3.1
E8	ORBITER FLIGHT SOFTWARE	X			PRORATA ANNUAL COST	1.3.2.1
E9	SIMULATOR OPERATIONS			X		
E10	CREW OPERATIONS			X		
E11	ENGINEERING SUPPORT		X			1.3.3.1
E12	ORBITER ANALYTICAL INTEGRATION, RECURRING	X			AVERAGE COST/FLIGHT	1.4.2.2
E13	ORBITER ANALYTICAL INTEGRATION, SUPPORT	X			PRORATA ANNUAL COST	1.4.2.2
E14	NOT ASSIGNED					
E15	PROGRAM MANAGEMENT, JSC	X			PRORATA ANNUAL COST	1.9.3.1
E16	PROGRAM SUPPORT, JSC	X			PRORATA ANNUAL COST	1.9.3.2
E17	DIRECT CIVIL SERVICE & RELATED COSTS, JSC	X			PRORATA ANNUAL COST	1.9.3.2
E18	INDIRECT CIVIL SERVICE & RELATED COSTS, JSC	X			PRORATA ANNUAL COST	1.9.3.2
E19	PROPELLANTS, KSC	X			AVERAGE COST/FLIGHT PLUS PRORATA ANNUAL COST	1.6.4.1
E20	GSE SPARES, KSC	X			PRORATA ANNUAL COST	1.6.5.3

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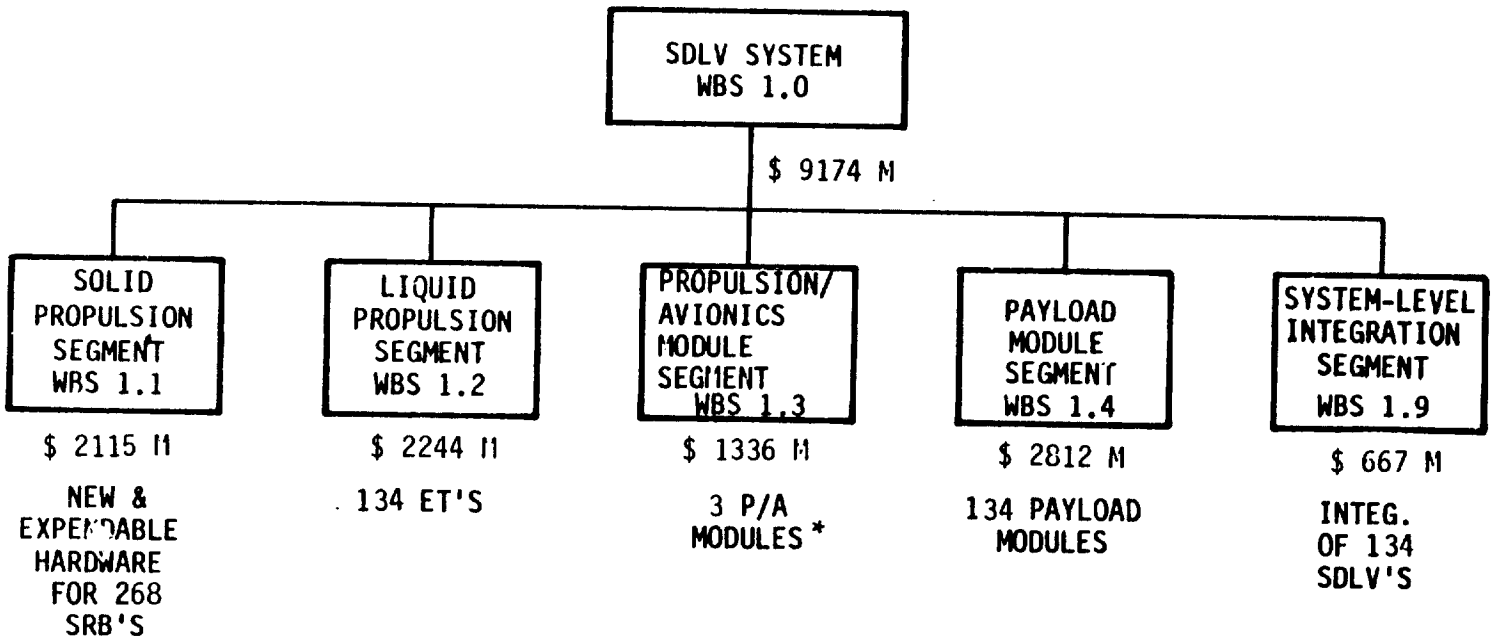
RECURRING PRODUCTION ESTIMATE



*ABOVE AN BEYOND REFURBISHED P/A MODULE FROM DDT&E PROGRAM

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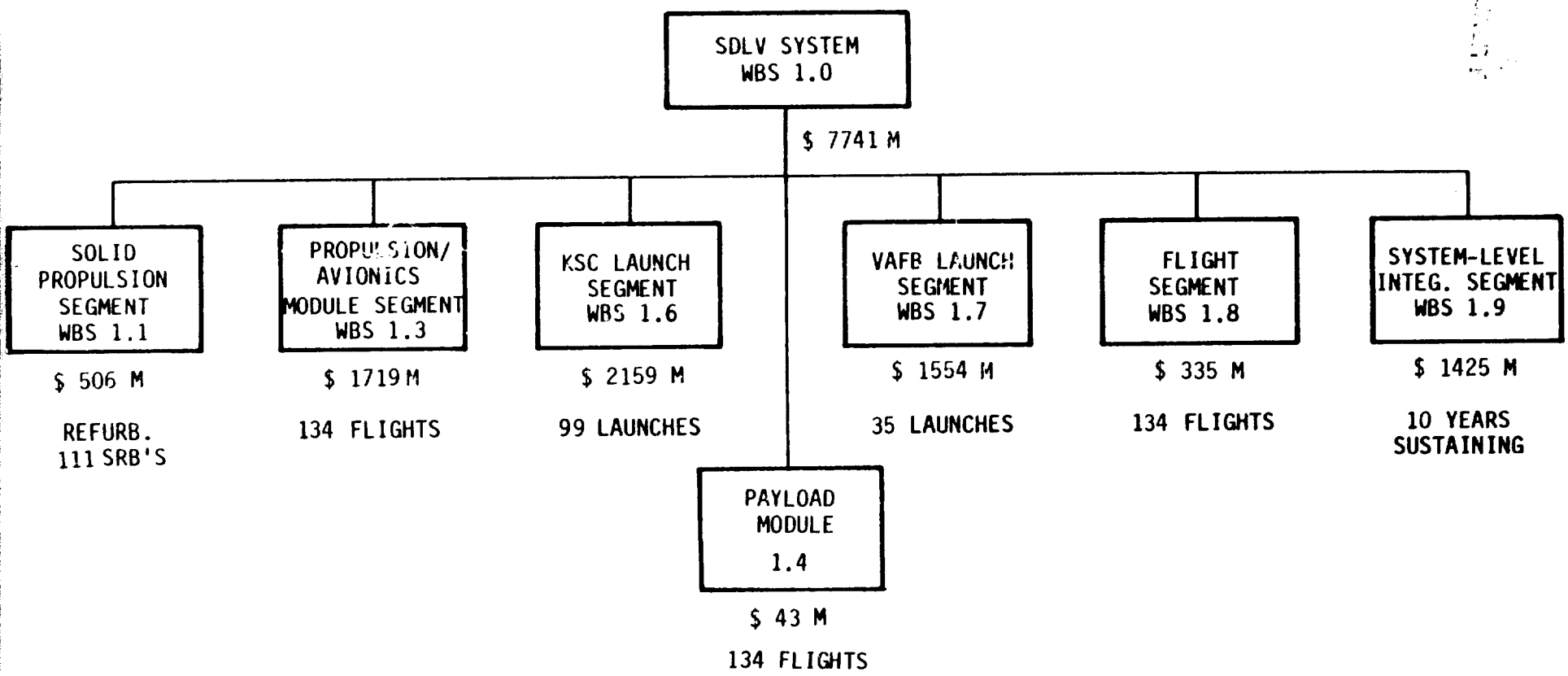
RECURRING OPERATIONS ESTIMATE



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MISSION OPTIONS

NUMBER OF FLIGHTS THROUGH YEAR 2000

	ALL FLIGHTS ON SHUTTLE	SHUTTLE/SDLV MIX		
	SHUTTLE	SHUTTLE	SDLV	TOTAL
LOW ACTIVITY	378	213	92	305
MODERATE ACTIVITY	675	367	134	501
HIGH ACTIVITY	801	462	167	629

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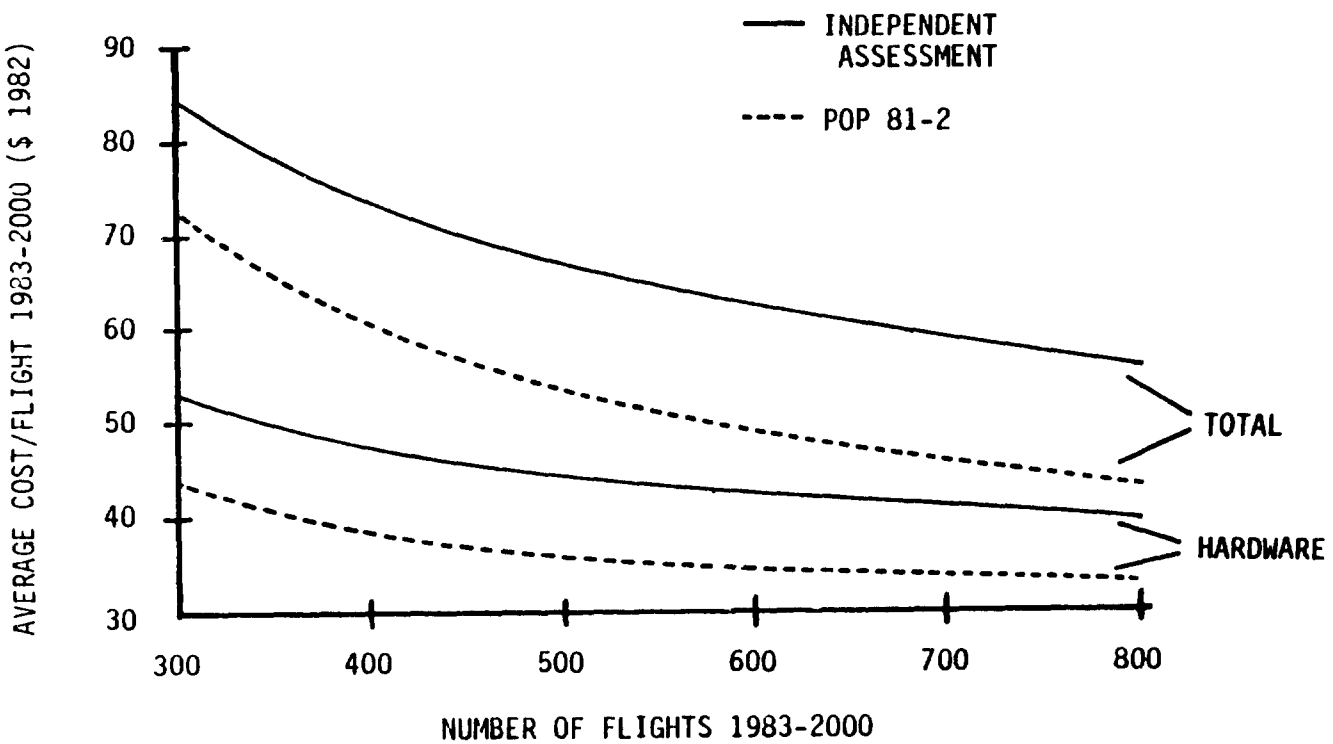
COST/FLIGHT SENSITIVITY TO SHUTTLE FLIGHT RATE

HARDWARE PLUS OTHER (NON-LAUNCH) SERVICES



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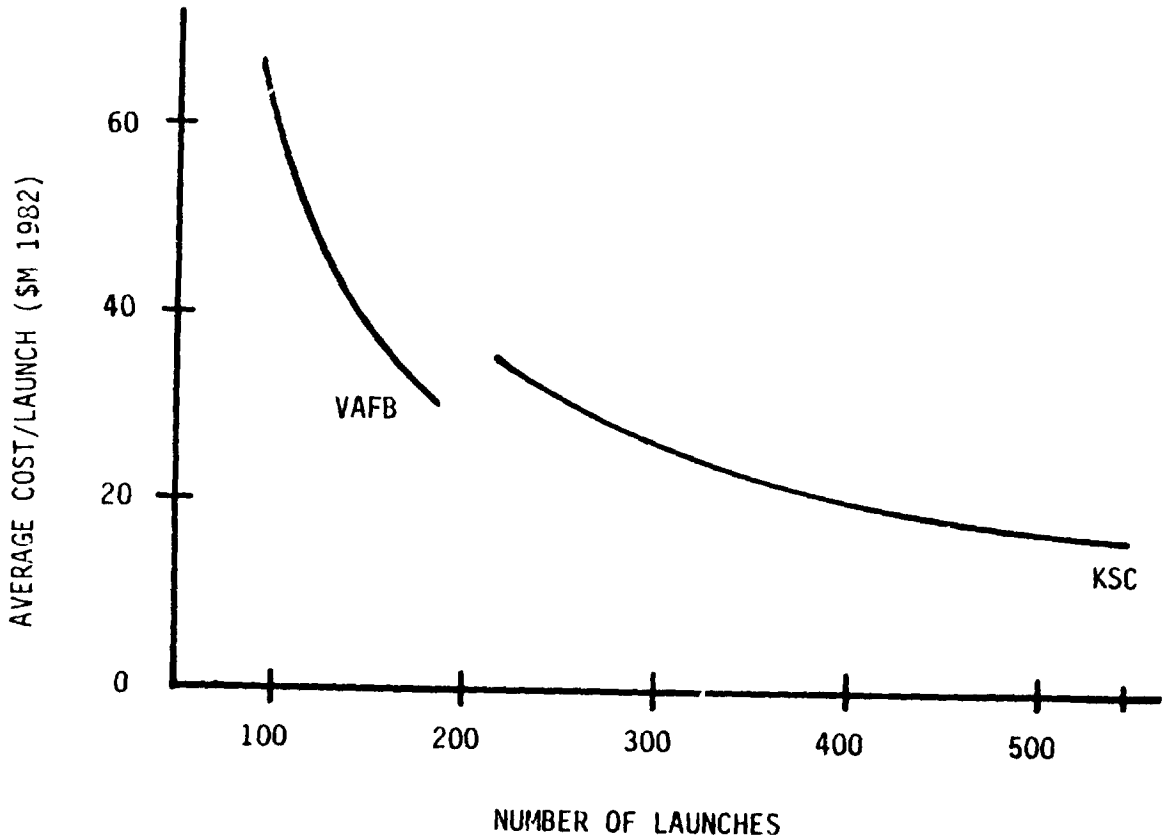
LAUNCH COST/FLIGHT SENSITIVITY



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RECURRING TRANSPORTATION COSTS

FOR STS ONLY CASE

($ M 1982)

	LOW ACTIVITY			MODERATE ACTIVITY			HIGH ACTIVITY		
	FLTS	AVG CPF	COST	FLTS	AVG CPF	COST	FLTS	AVG CPF	COST
HARDWARE	378	48.5	18,333	675	41.6	28,080	801	39.9	31,960
OTHER SERVICES	378	24.6	9,299	675	15.2	10,260	801	13.3	10,653
KSC LAUNCH	292	27.5	8,030	543	16.3	6,851	617	15.5	9,564
VAFB LAUNCH	86	57.8	4,970	132	40.5	5,346	184	32.5	5,980
			40,632			50,537			58,157

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RECURRING TRANSPORTATION COSTS

FOR SDLV/STS MIX

($ M 1982)

ELEMENT	LOW ACTIVITY FLTS	LOW ACTIVITY AVG CPF	LOW ACTIVITY COST	MODERATE ACTIVITY FLTS	MODERATE ACTIVITY AVG CPF	MODERATE ACTIVITY COST	HIGH ACTIVITY FLTS	HIGH ACTIVITY AVG CPF	HIGH ACTIVITY COST
SDLV & COMMON COSTS									
1.1 SRB	305	22.2	6,771	501	19.4	9,719	629	19.0	11,951
1.2 ET	305	19.1	5,825	501	16.7	8,368	629	16.1	10,127
1.3 P/A MODULE	92	12.8	1,178	134	12.8	1,715	167	12.8	2,138
1.4 P/L MODULE	92	23.6	2,171	134	21.3	2,854	167	20.2	3,373
1.6 KSC LAUNCH	235	33.6	7,896	386	21.8	8,414	484	18.0	8,712
1.7 VAFB LAUNCH	70	70.2	4,914	115	44.4	5,106	145	37.6	5,452
1.8 SDLV FLIGHT OPS.	92	3.1	285	134	2.5	335	167	2.3	384
1.9 SYS. INTEG.	305	17.7	5,398	501	10.6	5,311	629	9.8	6,164
STS UNIQUE COSTS									
ORBITER HARDWARE	213	7.9	1,683	367	6.6	2,422	462	6.0	2,772
ORBITER FLIGHT OPS.	213	11.8	2,513	367	9.9	3,633	462	9.2	4,250
			38,634			47,877			55,323

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COST COMPARISON AT EQUAL TRANSPORTATION CAPABILITY

(M 1982 $)

	LOW ACTIVITY		MODERATE ACTIVITY		HIGH ACTIVITY	
	STS	SDLV/STS	STS	SDLV/STS	STS	SDLV/STS
ACQUISITION COSTS						
DDT & E	N/A	2,257	N/A	2,257	N/A	2,257
PRODUCTION (P/A FLEET PLUS SDLV INTEGRATION)	N/A	2,002	N/A	2,002	N/A	2,002
SUBTOTAL		4,259		4,259		4,259
DIFFERENCE	-4,259		-4,259		-4,259	
RECURRING COSTS	40,632	38,634	50,537	47,877	58,157	55,323
DIFFERENCE	+1,998		+2,660		+2,834	
TOTAL COST	40,632	42,893	50,537	52,136	58,157	59,582
DIFFERENCE	-2,261		-1,599		-1,425	

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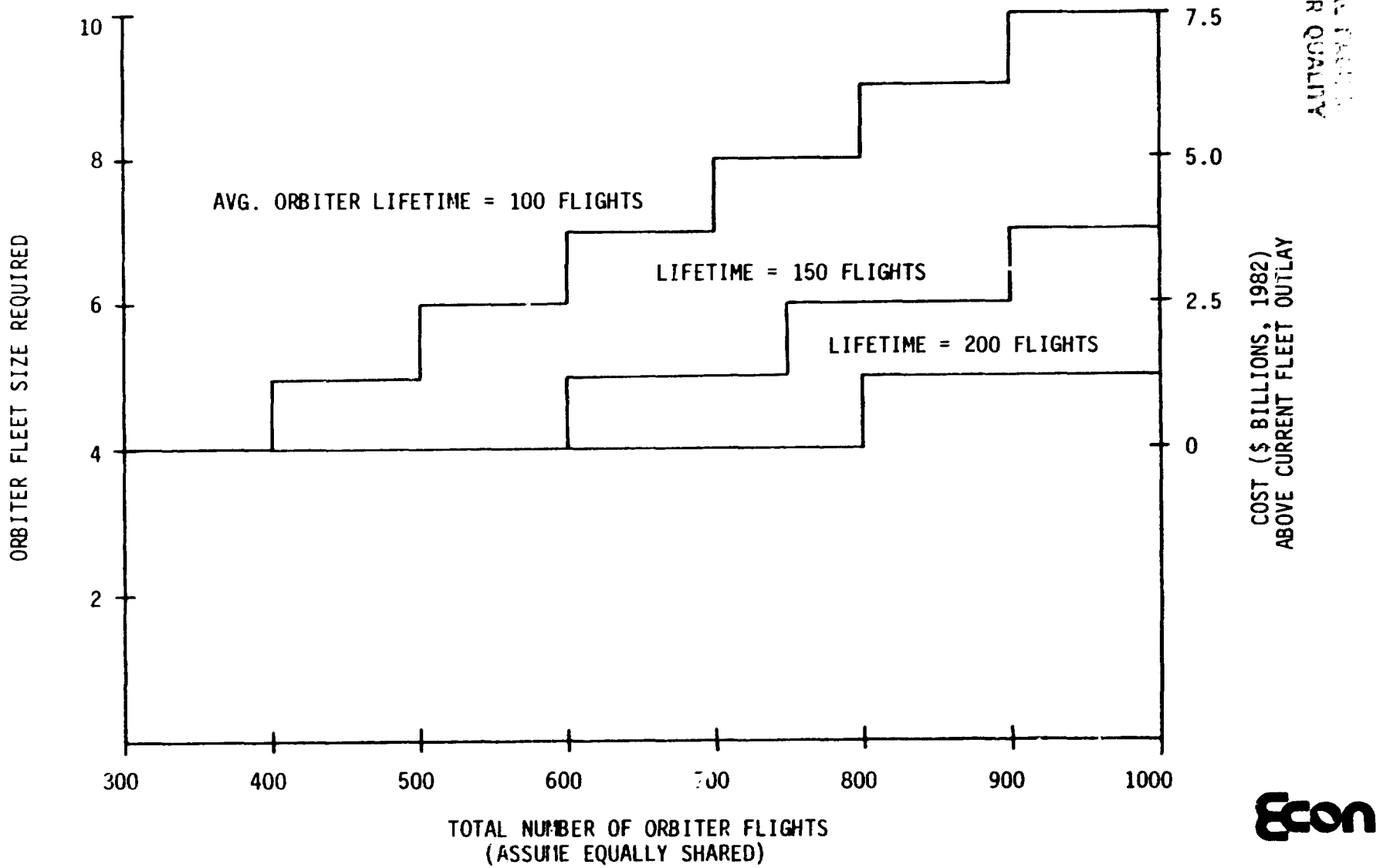
ORBITER FLEET SIZE & ADDED COST VERSUS ORBITER LIFETIME



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STUDY FINDINGS

SDLV SYSTEM CAN BE ACQUIRED FOR ABOUT $4.3 BILLION (1982):

- DEVELOPMENT PLUS ONE FLIGHT ARTICLE = $2.3 BILLION
- PRODUCTION OF THREE ADDITIONAL P/A MODULES = $2.0 BILLION

THESE ESTIMATES ASSUME:

- EXTENSIVE USE OF EXISTING SHUTTLE HARDWARE & SOFTWARE
- USE OF SHUTTLE FACILITIES ON NON-INTERFERENCE BASIS

COMPARISON OF STS WITH SDLV/STS MIX AT EQUAL TRANSPORTATION CAPABILITY SHOWS:

- RECURRING COST SAVINGS FAVOR SDLV ($2.0 B TO $2.8 B DEPENDING ON MISSION MODEL)
- ACQUISITION (NONRECURRING) COST SAVINGS FAVOR STS BY $4.3 BILLION
- OVERALL LIFE CYCLE COST SAVINGS FAVOR STS BY $2.3 TO $1.4 BILLION

HOWEVER, SDLV IS A GOOD INVESTMENT IF:

- UNIQUE SDLV MISSION PERFORMANCE ALLOWS SDLV ACQUISITION COSTS TO BE SUNK, OR
- SHUTTLE FOLLOW-ON PROCUREMENT CAN BE REDUCED BY MORE THAN ONE ORBITER

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